The Association between Ambient Air Quality

Ozone Levels and Medical Visits for Asthma

in San Juan County

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Abstract

The New Mexico Department of Health (NMDOH) Environmental Health Tracking Project has been compiling and analyzing data on air quality and respiratory health of New Mexicans. While other studies in the United States have shown an association between the frequency of asthma attacks and ground level ozone in large urban areas, few researchers have focused on largely rural communities in the desert southwest. To perform the analysis, the daily number of asthma-related emergency room visits to emergency departments for 2000 to 2003 were matched to daily ozone levels during April – September. The ozone concentration data were obtained from nationwide datasets compiled by the Environmental Protection Agency, but were collected by the NM Environment Department Air Quality Bureau. The study focused on ground level ozone during April to September because ground level ozone accumulates when warmer and longer days cause nitrogen oxides and volatile organic compounds in the air to react and generate ozone. These reactions can cause ozone concentrations to increase by more than 20 parts per billion (ppb) from one day to the next.

The analysis used a statistical model to predict the effect that these changes in ozone concentrations have on the number of asthma-related emergency room visits. Two health outcomes were considered: daily presence or absence of an asthma-related medical visit and the number of visits. Ozone was associated with asthma-related medical visits. The distribution of ozone concentrations was similar to that observed in many large cities. Increased ozone (lagged two days) was associated with increased odds of at least one asthma-related medical visit by 42 %. The study found that when ozone increased by 20 ppb the number of emergency room visits increased by about 34%. While this is a small increase in the number of visits, sensitive persons may want to monitor air quality index forecasts to help limit their exposure to ozone. Ozone concentrations typically are highest in the early afternoon, so sensitive individuals should try to reduce their outdoor activities during this part of the day.

Background

Exposure to air pollutants, such as ozone, nitrogen dioxide, sulfur dioxide and particulates, have repeatedly been shown to be associated with negative health outcomes, including mortality, reduced lung function growth and asthma (Dominici et al. 2003, Gauderman et al. 2000, Tolbert et al. 2000). However, most of these studies have been conducted in large urban areas, with many of these in the eastern United States or the western coast. The distribution of these air pollutants and the sources of these pollutants may differ considerably from rural areas or areas in the high desert Southwest.

In an Environmental Protection Agency (EPA) study of air quality in New Mexico, Sather showed that the ozone concentrations in San Juan County were increasing and were among the highest in EPA sites in the Southwest (Sather 2004). He further concluded that the levels were similar throughout most of the county and that NOx and alkanes were the main volatile organic compounds in the ozone development.

Health outcomes associated with air quality have not been studied in a rural, southwestern high desert environment. Thus, we conducted a study of asthma-related medical visits in San Juan County and present an alternative statistical approach that deals with some of the limitations of data obtained in a rural area.

Study Area

San Juan County, New Mexico is a rural county in the high desert of northwest New Mexico, with an elevation of 5145 feet and an average rainfall of 9.3 inches. The county covers over 5000 square miles, but had a population of 114,000 in 2000, resulting in a low density of 21 people per square mile. The main city is Farmington, with a population of 38,000. All other towns have a population under 10,000, with most being considerably smaller. Although the area is rural, the county residents are concerned about air pollution and the potential health risks, especially with respect to asthma. Major industries center on coal, oil and natural gas production. Air pollution sources include coal-based

power plants and production of gas and oil. Two more large coal-fired power plants may be built within the county. With the increased number of forest fires in the West and the hundreds of miles that the smoke from these fires has traveled, forest fires also have had a considerable impact on the air quality.

Asthma Surveillance

Through a CDC cooperative agreement starting in 2000, the NMDOH developed a statewide asthma surveillance system. With renewed funding NMDOH has continued surveillance and has expanded its role to education, improving access to care and reducing the effects of environmental factors associated with asthma. In 2003, NMDOH received funding through the CDC Environmental Public Health Tracking Program to link environmental exposure data with health outcome data. As part of this program, NMDOH, in collaboration with the UNM, linked data on air quality and asthma in San Juan County. Both hospitalization discharge and urgent care visit information were obtained through the statewide asthma surveillance system for January 1, 2000 through December 31, 2003. Age, sex and zip code of residence were obtained for each visit.

Air Quality Data

New Mexico Environment Department (NMED) collected air quality data from three monitors within the county. The Bloomfield and San Juan Substation monitors ran continuously and collected hourly data on air quality and weather conditions. While both monitors were operating as of January 1, 2000, ozone was not collected at the Bloomfield station until June 7, 2000. The Bloomfield monitor is approximately 15 miles east of Farmington in the town of Bloomfield. The Substation is located at the Shiprock Electrical Substation, approximately 15 miles west of Farmington, near the Public Service Company of New Mexico San Juan Generating Station, and a few miles north of the Arizona Public Services Four Corners Power Generating Station.

Methods

Statistical Methods

Two health outcomes were considered: the number of asthma-related medical visits per day and a binary indicator as to whether or not any medical visits during a day were asthma-related. Since we were primarily interested in the association of ozone levels with asthma-related medical visits, we restricted the yearly study period to May 1 through September 15, when over 90% of the eight hour average ozone concentrations were above 50 ppb. Variables for which data were collected hourly were summarized as both the daily maximum hourly value and the maximum eight hour average value. While the maximum eight hour value for ozone is used in regulatory standards, we also wanted to consider if shorter term peaks, such as those indicated by high daily maximum hourly values, may be important to health outcomes. For measurements taken at two stations, the association between the two daily ozone values was assessed and the maximum of the two values was used.

Modeling

The daily number of asthma-related medical visits was modeled using Poisson regression. Primary exposure variables were the maximum daily values for the eight-hour average hourly ozone concentrations. Lags of zero to five days from exposure to visit day were examined to determine the amount of time between exposure and effect. Covariates were included to adjust for seasonal components, year, week day, holidays (lagged zero to two days) and school year. Variables were included only if the significance level was less than 0.10. Single pollutant models were obtained by adding an exposure variable to this best covariate model. Only the variables significant at $p<0.10$ in the single pollutant models were examined in the overall model, but these variables were retained only if the significance level was less than 0.05. Since the number of daily visits generally was small, logistic regression was used to model whether or not any asthma-related medical visit was observed on a day. The same

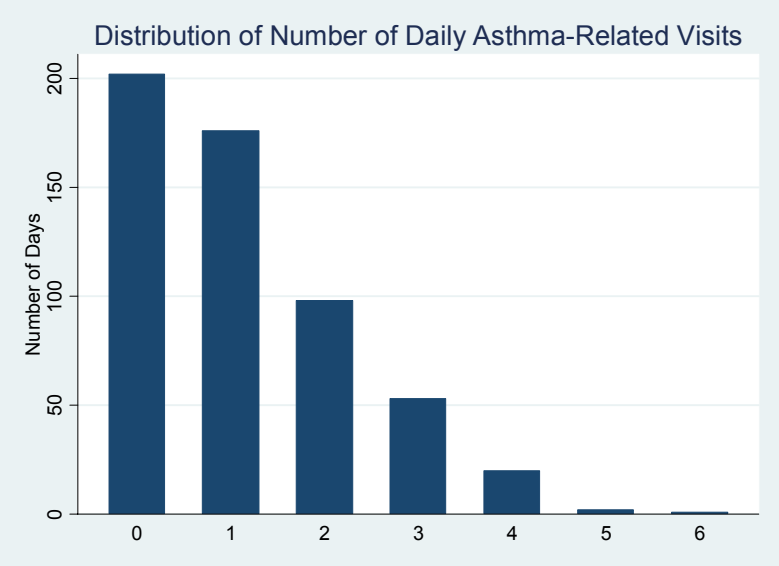
procedure, including the same predictor variables and covariates, that was used in the Poisson regression modeling was used in the logistic regression modeling.

Since the number of daily asthma-related medical visits was small and the number of days with zero counts was larger than expected under the Poisson model, the Zero-Inflated Poisson (ZIP) model also was used (Dobbie and Welsch 2001; Hall and Zhang 2004). This model contains two components: the first predicts the probability of observing at least one asthma-related visit in a day (binary component) and the second estimates the number of visits (count component). The coefficients in the two components are estimated simultaneously. Only variables significant at < 0.10 at entry were retained. All statistical modeling was done in R.

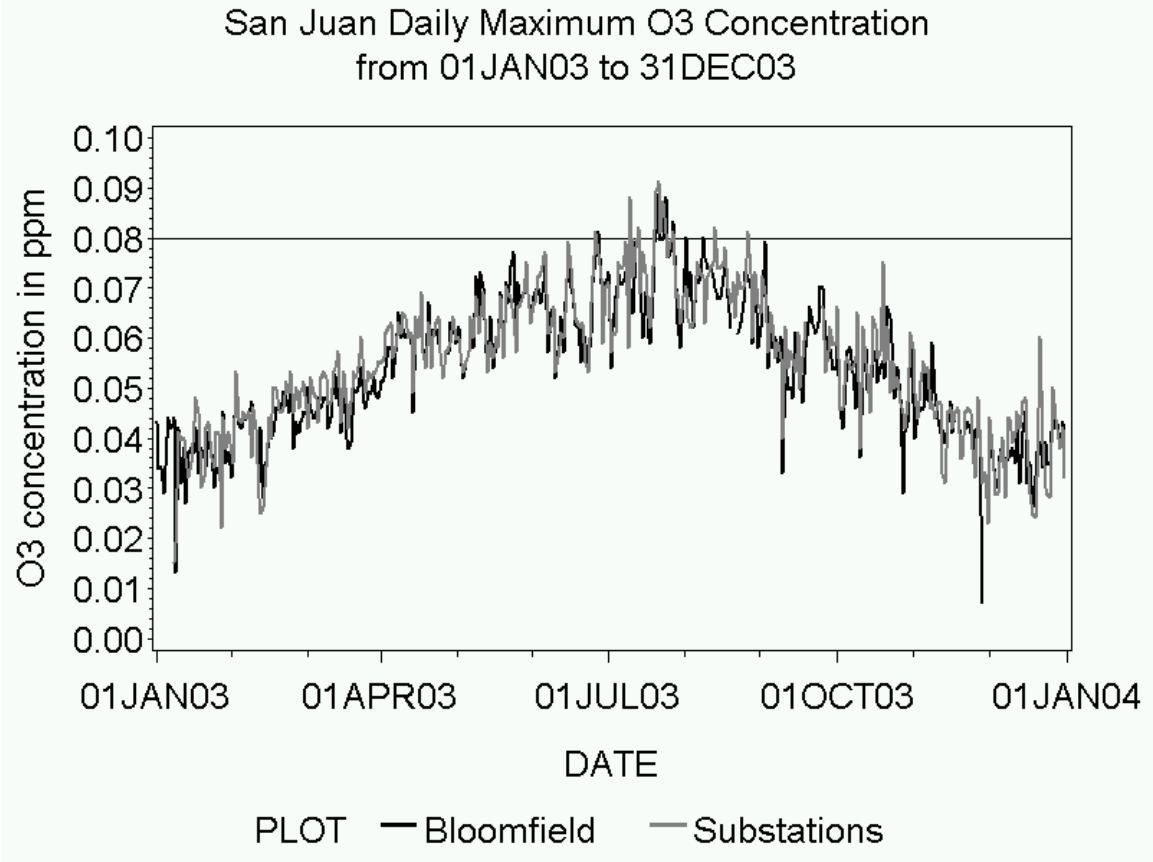
Results

Health Outcomes

During the summer months (May 1 through September 15) of 2000 through 2003, 627 asthma-related medical visits were reported in San Juan County. Asthma-related visits ranged from 0 to 6 per day, with a median of 1 and mode of 0 (Figure 2). At least one patient made an asthma-related visit on 350 (63.4%) of the 552 study days. Although age, gender and zip code information were available, the number of visits or proportion of days with an asthma-related visit were too low for successful modeling, so no assessment by these variables are included.



Air Quality: Ozone peaks during the summer months. Analyses were restricted to the summer months, from May 1 through September 15. Ozone concentrations at the two monitors were very similar. For air quality parameters that were measured at two monitors, the maximum value was used. The median daily eight hour maximum ozone level was 63 ppb during the summer months, with a maximum value of 85. All air quality variables exhibited distributions skewed to high values, but ozone was the least skewed. The maximum value for ozone was only 35% of the median.



Regression Models: To model the odds of at least one asthma-related medical visit, logistic regression models with adjustment for the seasonal components, weekday, holiday and spring school time were developed. The best lags were two days for ozone. Ozone was associated with increased odds of at least one asthma-related medical visit (OR=1.42; 95% CI: 1.09, 1.95; $p < 0.01$). To model the count of the number of asthma-related medical visits, Poisson regression models were also used with adjustment for the seasonal components, weekday, holiday and year. Ozone was associated with an increased count of visits, with a relative risk of 1.11 per 10 ppb ozone (95% CI: 0.98, 1.24). Zip models were used to simultaneously model the probability of any asthma-related medical visits and the number of visits per day. Adjustment factors were determined for the separate binary and count components, with no adjustment in the binary component and adjustment for the seasonal components, weekday, holiday and year in the count component. While ozone was significant in the binary component ($p<0.05$), the overall association was not significant ($p=0.09$).

Discussion

We have shown that ambient ozone concentrations are associated with asthma-related medical visits in a rural area of the high desert in San Juan County, New Mexico. While there is an indication that the number of visits rise along with increases in ozone, the most important result is that the odds of asthma-related visits increase with increasing ozone (1.42; 95% CI: 1.09, 1.85).

The basic association of increased asthma consequences with increased ozone has been shown in many urban areas. The distribution of ozone values in San Juan County is similar to those observed in other studies, but the extreme values are not necessarily as high in San Juan County. For example, while the highest single hour and eight-hour averages were 96 ppb and 83 ppb in San Juan County, respectively, studies in Atlanta had maximum one hour concentrations of 132 ppb, (Stieb et al. 1996; Tolbert et al. 2000). However, studies in Seattle (8-hour maximum=83.1 ppb) and Santa Clara County, CA (1-hour maximum=70 ppb) had similar, but slightly lower maximum concentrations (Lipsett et al. 1997; Norris et al. 1999).

The high values in San Juan County are of concern. The federal regulatory standard is 84 ppb for the three-year average of the annual fourth highest eight hour average. During the study period, the county reached a three-year average of 78 ppb. Furthermore, in an EPA study of air quality in New Mexico, Sather concluded that the ozone concentrations in San Juan County during 2000-2003 were higher than the previous three years and were among the highest among EPA regional sites in the Southwest including Arizona, Utah, Colorado, New Mexico and Texas (Sather 2004). Sather also showed that ozone was high in many parts of the county, including the middle of the county near the population center and the sparsely populated western and northeastern parts of the county. The largest hourly change in ozone concentrations was only 18 ppb, indicating that nitrogen oxides and alkanes were the main compounds in the ozone development. Similar to studies of urban areas, the most effective lag is two days between the occurrence of the ozone concentration and the asthma-related visits (Hwang et al. 2004; Stieb et al. 1996).

Studies to address health issues in rural areas are more often hampered by small counts than similar studies in urban areas. Use of standard methods such as Poisson regression may not be appropriate, and the modification of the data to look at binary outcomes may lose vital information. Thus, a model such as the ZIP model may be appropriate in many rural health studies, as in other studies with small counts.

This study includes several limitations. As discussed above, studies in rural areas are often limited by small sample sizes. However, our modeling approach effectively dealt with small, including zero, counts. While the county covers a large area, there were only two monitors for each air quality parameter. Furthermore, address information was limited to zip code, so there was no effective method to obtain better exposure information than that obtained from one monitor or the average of two monitors. However, we did limit the study sample to people residing in the county. Prior studies of the spatial trends in ozone indicated some but not significant differences in ozone across the county.

Conclusions

Although a rural area, San Juan County, New Mexico experiences high ozone concentrations, as high as some urban areas and high for the Southwest. The analysis used a statistical model to predict the effect that these changes in ozone concentrations have on the number of asthma-related emergency room visits. Two health outcomes were considered: daily presence or absence of an asthma-related medical visit and the number of visits. Ozone was associated with asthma-related medical visits. The distribution of ozone concentrations was similar to that observed in many large cities. Increased ozone (lagged two days) was associated with increased odds of at least one asthma-related medical visit by 42 %. The study found that when ozone increased by 20 ppb the number of emergency room visits increased by about 34%. While this is a small increase in the number of visits, sensitive persons may want to monitor air quality index forecasts to help limit their exposure to ozone. Ozone concentrations typically are highest in the early afternoon, so sensitive individuals should try to reduce their outdoor activities during this part of the day.

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